EVENTO HIDROMORFOLÓGICO DE FEVEREIRO DE 1979 – CONDIÇÕES ATMOSFÉRICAS E IMPACTOS

THE HYDRO-GEOMORPHOLOGIC EVENT OF FEBRUARY 1979 – WEATHER CONDITIONS AND IMPACTS

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SUMMARY

The large amount of floods and landslides that occurred on 5-16 February 1979 in Portugal corresponds to a major hydro-geomorphologic event according to the comprehensive DISASTER database. This event is driven by atmospheric forcing at different time scales that have not been, as yet, studied in detail. Here we show that the precipitation period of February 1979 has produced several multiday accumulated precipitation events, over the Portuguese continental territory, ranking amongst the top 10 events observed between 1950 and 2008. Additionally, most of the precipitation on this event occurs in days with *atmospheric circulation dominated by "wet" circulation weather types (CWTs), i.e. cyclonic (C), west (W) or southwest (SW) types.*

1. Introduction

It has been well known that extreme precipitation events in Portugal occurring during winter months (December-March) are often associated with flooding in the major river basins (Pereira et al., 2016; Trigo et al., 2014), and also, with flash floods mostly in small watersheds or urban areas (Trigo et al, 2016). These events can affect many people, as well as impinging major material damages. Thus there is a clear need for better characterization of extreme phenomena and the nature of their driving mechanisms, in order to prevent and manage the associated impacts and risks.

The spatial characterization of past floods and landslides with important human consequences in Portugal since 1865 has been undertaken recently, within the context of the DISASTER project (Zêzere et al., 2014). Using this database, some event specific studies have also been undertaken with the purpose of characterizing the respective meteorological drivers, e.g. the record flood events of Tagus and Guadiana in 1876 (Trigo et al., 2014) or in Duero; (Pereira et al., 2016).

For this work we have selected the February 1979 event as it corresponds to the top ranked event in the DISASTER database regarding the total number of affected people for both Portugal and the Tagus basin (18578 and 14322, respectively). Therefore, we aim to present in detail the socio-economic impacts of the February 1979 event and to characterize the associated atmospheric forcing's.

2. Methodology

2.1. Historical data sources

The human impacts of the February 1979 event were obtained from the DISASTER Database, updated for the period 1865-2015. The entry criteria for the database are the following: any flood or landslide that, independently of the number of affected people, caused casualties, injuries, evacuated or homeless people reported by national and regional newspapers (Zêzere et al., 2014).

A DISASTER case is a unique hydro-geomorphologic occurrence, which fulfils the DISASTER database criteria and is related to a unique space location and a specific period of time. Each DISASTER case includes details on the physical process characteristics and on its associated human and structural damages (Zêzere et al., 2014). DISASTER cases were located using a point shapefile.

DISASTER cases are grouped in a more restrict number of DISASTER events sharing the same trigger in time, according to the following criteria: (i) include at least 3 Disaster cases; (ii) include Disaster cases with 3 or less interval days; (iii) Disaster events must have spatial coherence.

2.2. Precipitation data

A daily gridded precipitation dataset for the Iberia Peninsula (IP) was used in this work (IB02). This database consists of two joint precipitation datasets, produced with similar methodology, but developed independently for both Portugal (PT02, Belo-Pereira et al., 2011) and Spain (SPAIN02, Herrera et al., 2012). This dataset spans from 1950 to 2008 with a resolution of 0.2° latitude–longitude grid and is based on a dense network of rain gauges (up to 2000 for Spain and 800 for Portugal). This large number of rain gauges is crucial to allow meaningful regional assessment of extreme precipitation over medium-sized river basins.

This gridded dataset has been used recently on a number of high-resolution precipitation studies focused over IP. The general aim of these studies has been, (i) to explore which co-located synoptic patterns and dynamic mechanisms explain the occurrence of precipitation events over IP and its spatial-temporal variability, (Trigo et al., 2015; Ramos et al., 2015; Ramos et al., 2014b; Liberato et al., 2012); and (ii), to evaluate the extremeness of the daily and multi-day precipitation events over IP in regard to their aggregate magnitude (Ramos et al., 2014a; Ramos et al., 2016).

2.3. Precipitation magnitude

The aggregate magnitude of the February 1979 precipitation event was obtained using the same methodology devised in (Ramos et al., 2016) for the estimation of the multi-day precipitation extremeness. This method allows to characterize each day (or set of days) taking into account the severity of the precipitation event, as well as, the associated spatial extension. Firstly, daily normalized precipitation anomalies (N) for each day of the event in a specific year (c) were computed over every grid point (i, j) of the IB02 dataset (see Equation 1). This is followed by the summing of these daily precipitation anomalies for the entire period (p) of the desired event (see Equation 2). Finally, the magnitude of the precipitation event (R_M) was computed by multiplying the percentage area (A) of IB02 gridded points where the normalized precipitation anomaly stands above two standard deviation (std) by the respective average value of the normalized anomaly over these same gridded points (M), (see Equation 3).

$$N_{c,i,j} = \frac{Prec_{c,i,j} - \mu_{c,i,j}}{\sigma_{c,i,j}} \qquad (1)$$

,where *Prec* is total precipitation value, μ is the daily mean climatological value, and σ is the daily *std* climatological value.

$$\boldsymbol{NCC_{p,i,j} = \sum_{c=1}^{n} N_{c,i,j}} \qquad (2)$$

$$\boldsymbol{R_{M_{p,A}} = A_{>2std_p} \times M_{>2std,A}} \qquad (3)$$

The 2std threshold corresponds approximately to the 95 percentile of the daily precipitation distribution throughout the IP domain in the extended winter months. It ensures a robust limit that is similar to the 95th percentile threshold often used in similar studies.

2.4. Circulation weather types

In this study we applied the circulation weather types (CWT) classification methodology developed by Trigo and DaCamara (2000) for Portugal. This method takes into account physical and geometrical considerations, including the direction and strength of airflow, the direction and vorticity of geostrophic flow, and the signal and intensity of cyclonicity. The large-scale meteorological fields were extracted from the 20th Century Reanalysis dataset v2 between 1851 and 2014 (Compo et al., 2011).

3. Results

3.1. Socio-economic impacts

The IP was spatially affected during this event mainly along the margins of the Douro, Mondego and Tagus rivers. It recorded a total of 67 reported hydro-meteorological Disaster cases - 62 floods and 5 landslides. For the Douro and Mondego basins the damaging floods tend to concentrate in the cities of Oporto and Coimbra, respectively, while in the Tagus basin the floods appear distributed along several riverside localities of the lower Tagus valley, namely, Santarém, Abrantes, Vila Franca de Xira and other smaller villages (Figure 1).

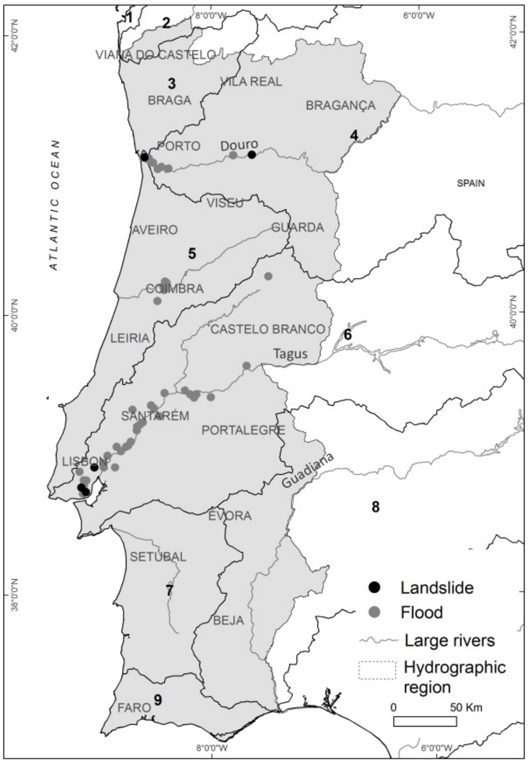

Figure 1. Flood and landslide disaster cases from 5-16 February 1979 event in Portugal. Note: (1) Coruña basins; (2) Minho Basin; (3) Lima and Cávado basins; (4) Douro Basin; (5) Águeda, Mondego, and West basins; (6) Tagus Basin; (7) Sado Basin; (8) Guadiana Basin; (9) Algarve basins.

The February 1979 event corresponds to the top ranked event in the DISASTER database regarding the total number of affected people (18 578). Moreover, this event is also the top one in each of the Tagus, Douro and Águeda, Mondego, and West basins, when the top 5 events are considered individually (Figure 2). The Tagus basin was the most heavily affected during this event with almost the double of total affected people than those reported for the Douro basin (Figure 2).

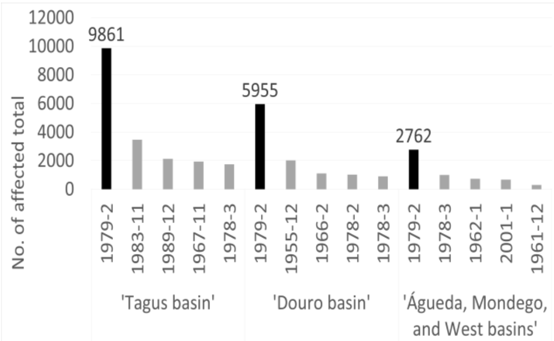

Figure 2. Top five ranked Disaster events regarding the total number of affected people in each of the Tagus, Mondego and Douro basins. The February 1979 event is highlighted in black.

Additionally, the type of human impacts shows that most of the damages resulted on homeless and evacuated people (14 322 and 4244, respectively). We should also notice that all of the eight casualties registered during this event were caused by landslides, five of them in Peso da Régua and the other three in the Tagus valley.

The regional distribution of Disaster cases, by process type, indicates that the majority of cases correspond to floods. Additionally, for the Tagus basin, seven flash flood cases were reported, all of them on the 10th of February in the city of Lisbon and nearby cities of Loures and Odivelas.

In Figure 3 we see that most of the DISASTER cases and associated human impacts reported for the two most affected basins on the event (the Tagus and the Douro basins) are concentrated between 9 and 14 February. However, the Tagus concentration begins and ends slightly earlier (9-13 February) when compared with the Douro basin (11-14 February). Nonetheless it is important to note that no linear relationship can be observed for the association between the daily number of reported Disaster cases and the corresponding human damages.

3.2 Precipitation event

Accumulated precipitation affecting Portugal during the 1979 event (Figure 4) shows that this evolved from slightly under the 90th percentile threshold of the hydrologic year's climatological series on 5 February to close the 95th percentile threshold in 16 February. This suggests that a period of continuous intense precipitation occurred over Portugal during the event.

Additionally, the winter season (Dec-Mar) shows a similar accumulation trend to that of the beginning of the month of February. For this, we find reasonable to suggest that some of the continental basins and/or reservoirs over Portugal might have had an already shortened storage capacity made available by the time the February event ensued.

Figure 5 presents the daily accumulated precipitation between 31 January and 22February, 1979. The figure shows that extreme daily precipitation values occurred for the majority of the event, both over continental Portugal and Tagus basin. On the whole, only three days out of the whole fifteen day event (7, 15 and 16 of February) fail to exceed the 90th percentile threshold for total daily precipitation, and two days (9th and 10th of February), exceed the 99th percentile threshold.

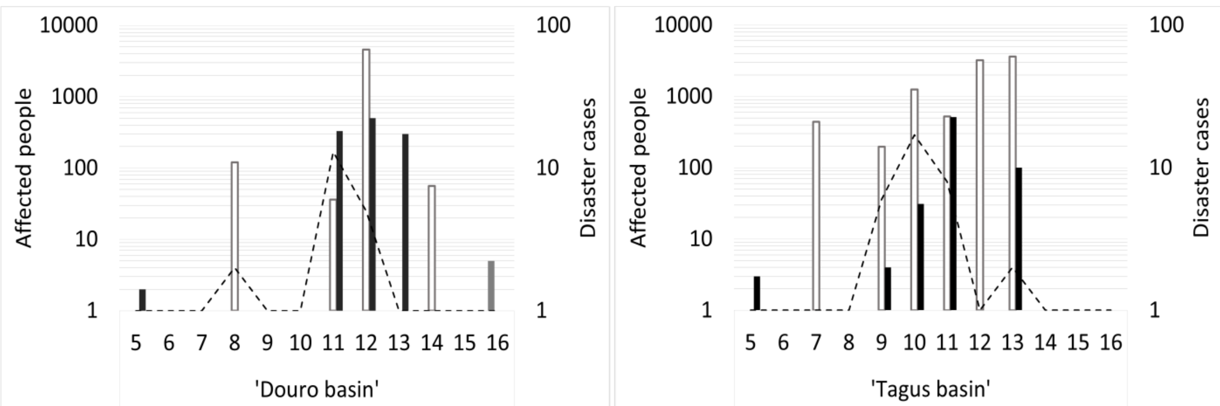

Figure 3. Daily event progression regarding number of homeless people (grey outlined columns), evacuated people (black columns), fatalities (grey filled columns) and reported cases (black dashed line).

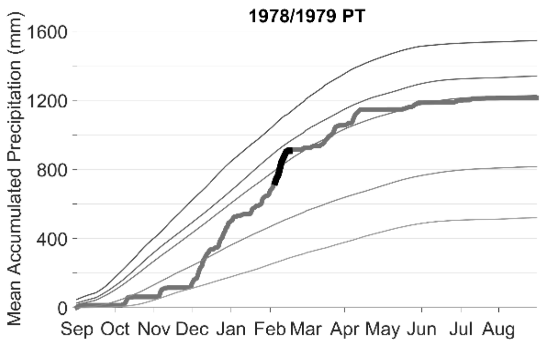

Figure 4. 1978/1979 hydrological year precipitation accumulation over Portugal (bold grey line) plotted against the respective 10, 75, 90, 95 and 99 percentile thresholds (from the bottom to the top) of the hydrological year's climatological series. The Disaster event days are marked in black.

The spatial distribution of the daily accumulated precipitation is represented over IP in Figure 6. A total of six daily maps offer an overview of the geographical distribution of the precipitation event plotted against the climatological series 75th, 90th and 95th daily precipitation thresholds. This figure presents two precipitation moments, each one describing a set of three sequential days. The final days of the event were not included in this figure.

During the initial phase of the event (from 4to 6February) precipitation was abnormal, above the 95th threshold, for the north and central regions of Portugal, with the Douro, Minho, Águeda, Mondego, and West basins receiving the bulk of the intense precipitation. At this time, the Tagus basin recorded some precipitation mostly in the Castelo Branco district, with just a few areas over the 90th threshold.

Then, from 8to 10February, precipitation expanded regionally towards the south and centre of the IP, producing abnormal precipitation over the majority of the Iberian Tagus basin. However the centre-north and north of Portugal remained mostly above the 90th percentile threshold, with variable sized areas registering at times precipitation above the 95th precipitation threshold. Overall the 9 and 10 of February were the two rainiest days of the event.

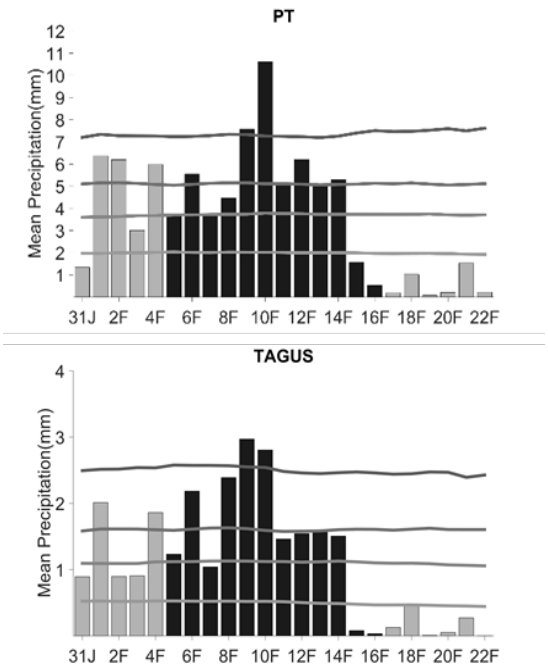

Figure 5. Daily mean precipitation (columns) during the February 1979 Disaster event in Portugal (top panel) and the Tagus basin (bottom panel). Precipitation plotted against the 99th, 95th, 90th and 70th percentiles (lines, from top to bottom) of the daily precipitation series. The event days are highlighted in black.

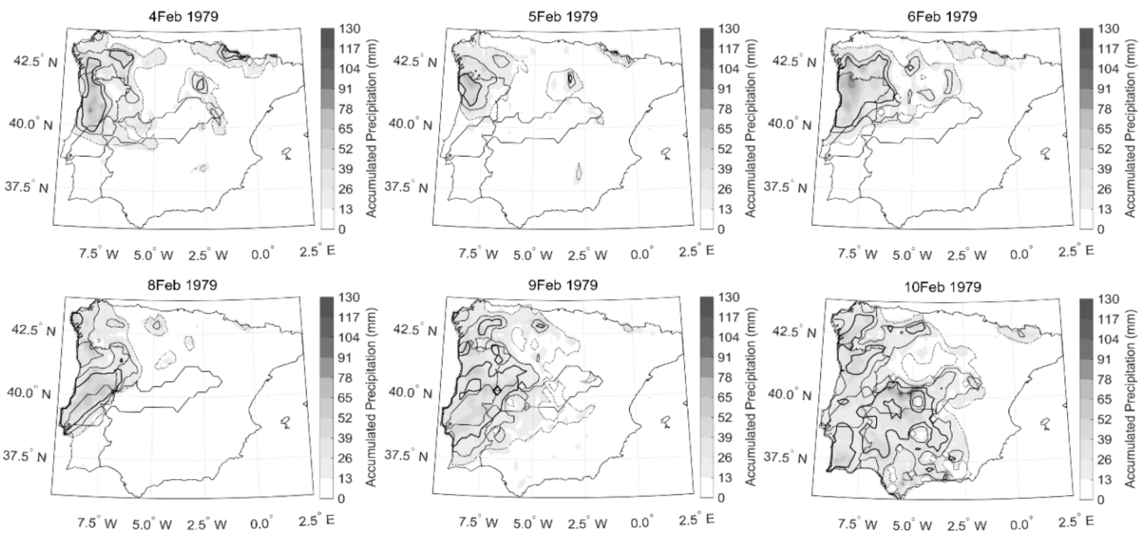

Figure 6. Daily accumulated precipitation distribution over IP for the days 4, 5, 6, 8, 9 and 10 of February. The accumulated precipitation is presented with the respective daily precipitation thresholds of the 75th (light dashed grey line), 90th (light grey line) and 95th percentiles (black line).

By the end of the event, i.e. from 12 to 14of February, the intense precipitation retreated back to the northwest of the IP producing abnormal rainfall mostly over the Minho, Douro and Mondego basins (considering only Portuguese territory). The Portuguese Tagus basin registered some precipitation above the 75th precipitation threshold, mostly in Castelo Branco and somewhat in Portalegre, Santarém and Vila Franca de Xira.

Figure 7 shows the standard deviation anomalies produced by the accumulated precipitation during the event over the IP domain. The multiday event produced high values of standard deviation anomalies for most of the IP domain, with the highest standardized anomalies over Portugal, being found, on the Minho and Douro basin (> 18 *std*), followed by the Águeda, Mondego, and West basins (> 10 *std* and 14 *std*) and the Tagus basin (> 6 *std*, 10 *std* and 14 *std*).

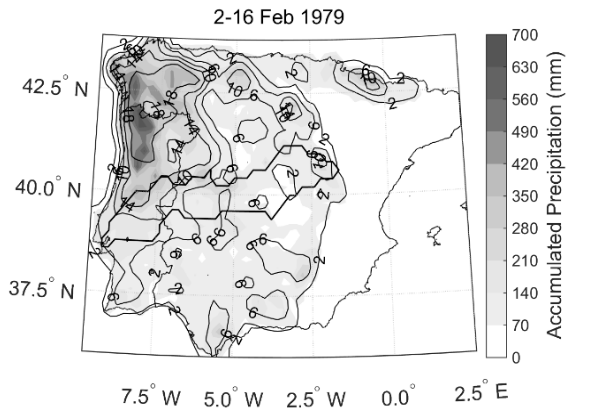

Figure 7. Accumulated precipitation standard deviation anomalies over the IP, for the total days of the event (2-16 February 1979)

The computed composite magnitude of the 15-day precipitation event was compared to all other IB02's 15-day precipitation events composite magnitudes for the Tagus region. The resulting ordered distribution is presented below (Figure 8 top panel). In this figure an abnormal precipitation magnitude is observable for the Tagus basin, for the period of the event, reaching almost the 99th percentile threshold. Aditionally, several other 15-day periods with abnormal precipitation magnitudes (e.g. near or above the 99th percentile threshold) can be observed during the two weeks that precede the 1979 February event. This results suggest that both, the 15 days prior to the 1979 Disaster event, and, the days of the 1979 Disaster event, supplied the Tagus basin with a prolonged and extreme rainfall contribution.

Figure 8 bottom panel shows that during the event, the highest daily precipitation magnitudes estimated for the Tagus basin were registered on the days between 8 and 11 February, mostly coinciding with the harshest numbers of human casualties and reported Disaster cases for the same event, on that same region (i.e. from 9 to 13 February).

The production of winter precipitation over Portugal is generally well correlated to the occurrence of wet circulation weather types (CWTs) over the IP. Approximately two-thirds of all of the climatological annual winter precipitation in Portugal is co-located with the occurrence of these wet CWTs. The same is true for this February 1979 Disaster event as the computations made for its daily CWT values and daily average precipitations (Figure 9 top panel), show that, from the last 10 days of January onwards until 16 February (when the event ends), the predominant daily CWTs over IP are the wet CWTs (SW, W, NW and C) and they coincide with a period spanning several days of high daily and aggregated precipitation values.

This same relationship can be observed on several other multi-day periods during the hydrologic year, particularly during the December to March winter season.

On further detail, we can see that the predominant CWTs occurring during this event are the west (W), southwest (SW) and cyclonic (C) types, both in number of occurrence days and number of correlated

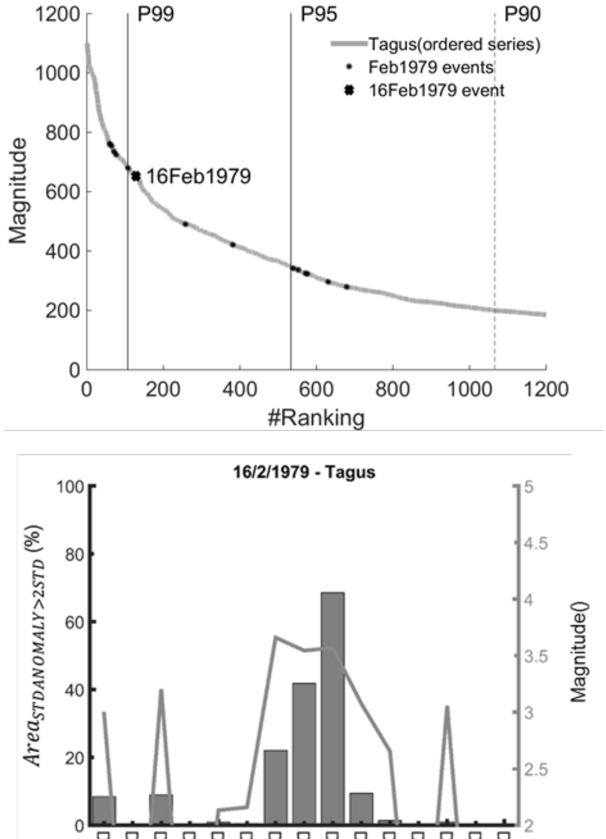

Figure 8. Ordered distribution of precipitation magnitude indexes (M) computed for every 15-day winter precipitation periods available in the IB02 dataset, considering the Tagus basin domain (top panel). The 99th, 95th and 90th percentile threshold values for the distribution are plotted as vertical lines. Daily precipitation magnitude values estimated for each day of the February 1979 Disaster event, considering the domain over the Tagus basin (bottom panel).

Disaster cases (Figure 9, bottom panel).

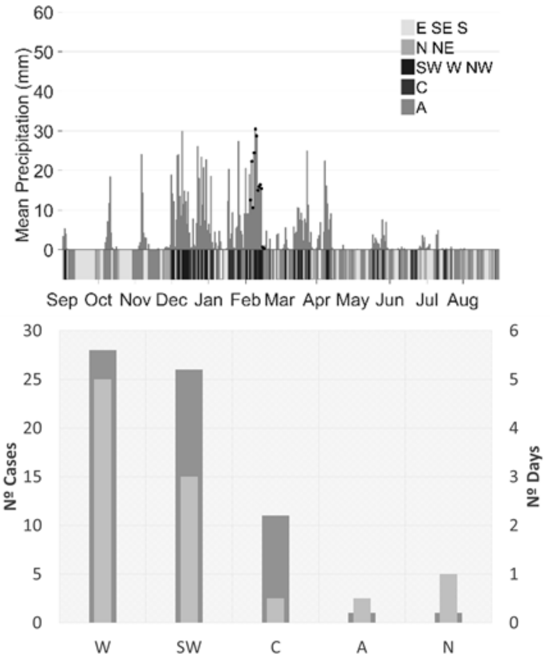

Figure 9. 1978/1979 hydrological year timeline over Portugal presenting the estimated daily CWT values (bottom coloured greyscale bars) and the corresponding daily mean precipitation values (top panel). Disaster event days are marked with black point markers. Number of daily CWTs during the February 1979 Disaster event considering a pure CWTs classification (bottom panel) (light grey bars/right axis) and number of Disaster cases (dark grey bars/left axis).

4. Conclusions

The February 1979 event is the top ranked event in the DISASTER database (since 1865) regarding human impacts for each one of the three Portuguese main hydrographic regions affected – Douro, Mondego and Tagus. This event is mainly characterized by progressive flooding occurring along the lowland sectors of each's basin main river, with the majority of the cases and affected people concentrating along the Tagus river floodplain.

The February 1979 event is framed within a twenty to twenty-five day period of very high and abnormal, daily, multi-day and hydrologic year precipitation totals for most of the Portuguese continental territory. For the Tagus region this period presents several 15-day periods with composite precipitation magnitudes consistently near or over the 99th percentile threshold of the long-term (1951-2008) precipitation dataset series distribution.

During this event, the highest daily precipitation magnitudes for the Tagus region appear on the period spanning between 8and 11 February, coinciding with the harshest numbers of human damages registered on the same basin during the event (9to 13February).

Most of the precipitation on this event occurs in days of *wet* CWTs, i.e. cyclonic (C), west (W) or southwest (SW) types, which agrees with the assessment obtained by Trigo and DaCamara (2000).

Acknowledgements

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